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CAMERON STATION ALEXANDRIA, VIRGINIA

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INVESTIGATION OF MIXTURES OF HYDRAZINE, HYDRAZINE
NITRATE AND WATER

Quarterly Progress Report, 3rd Quarter

Prepared by

R. D. Dwiggins, B. F. Larrick and
E. F. Davis

ABSTRACT: Investigations being pursued during the fiscal
year 1953 include the following topics: (1) Reaction rate
studies at high pressures, (2) Ignition studies, (3) Stability
and compatibility of solutions, (4) Impetus measurements, and
(5) Detorability, Equipment is now being received for burning
rate studies at pressures up to 30,000 psi. The bomb and
apparatus for reaction rate studies at pressures up to 100,000
psi have been installed and are being tested. An ignition
study bomb was designed and preliminary tests are being made.
Stability and compatibility tests have been continued at
ambient temperature and a modified apparatus is described for
extending these tests to 165°F. A method is presented for
applying heat loss corrections to the maximum pressures obtained
in bomb firings. This will permit more reliable determination
of impetus. Further data obtained in the evaluation of methods
for analysis of hydrazine, ammonia, and hydrazine nitrate
mixtures are presented.

NAVORD **Report** 2715   9 January 1953

The material presented in this Report was obtained under
Task NOL-Re2d-12-1-52, Liquid Propellants for Guns. This
Report is in the nature of a progress report covering the
period from 1 July to 30 September 1952. Since these inves-
tigations are continuing, the data and conclusions presented
should be regarded as tentative pending completion of the
project.

References

(a) BuOrd Conf ltr Re2d-WES:ltm NP51 Ser 18683 of 27 Mar
    1951 - NOL file NP/NOL/X21(15)
(b) NAVORD Report 2255, "Investigation of Mixtures of
    Hydrazine, Hydrazine Nitrate and Water", Dwiggins et al.
(c) NAVORD Report 2563, "Investigation of Mixtures of
    Hydrazine, Hydrazine Nitrate and Water", R. D. Dwiggins
    and B. F. Larrick
(d) Crow and Grimshaw, "On the Equation of State of Propellant
    Gases", Phil. Trans. Roy. Soc. London A230, 1932

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By direction

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ILLUSTRATIONS

INVESTIGATION OF MIXTURES OF HYDRAZINE, HYDRAZINE NITRATE AND WATER

INTRODUCTION

1. The Laboratory by reference (a) was assigned a general task for the investigation and evaluation of liquid propellants for guns. Work completed has been reported in references (b) and (c). The program for the fiscal year 1953 includes the following topics: (1) Investigation of reaction rates at high pressures, (2) Ignition studies, (3) Stability and compatibility of solutions, (4) Impetus measurements, and (5) Detonability investigations.

Part I - Reaction Rate Studies at High Pressures

2. Reaction rates will be determined by burning a column of the hydrazine-hydrazine nitrate solution and measuring the velocity of the advancing reaction front. The tests will be conducted in a large volume bomb pre-pressurized to selected pressures with nitrogen or helium. In this way quantitative data on the variation of burning rate with pressure may be obtained. This work will be divided into two parts. The first experiments will be conducted at pressures from 5,000 psi to 30,000 psi, while the second part of the work will determine burning rates at pressures from 30,000 to 100,000 psi in a specially designed high-pressure bomb.

3. The bomb to be used for burning rate studies at pressures up to 30,000 psi has a volume of 840 cc. This volume may be varied by placing inserts into the cavity. The pressurizing gas will be drawn from regular cylinders and compressed by a motor-driven gas booster pump to the desired operating pressure. The solution to be tested will be placed in a polystyrene or glass tube through which fine copper wires are sealed at one-inch intervals. Small resistors are arranged around the sample tube and connected to the burn-out wires so that breaking of a wire will produce sufficient signal to be pictured on an oscilloscope. The details of this arrangement are given in Figure 1. The burning rate tube will be potted into a 1" pipe which can be inserted into a well in the bottom of the bomb. Electrical contact through the cap of the bomb is provided by two electrodes. The cap is held by eight 3/4" bolts. The pressurizing pump and accessories are scheduled for early delivery so that work can soon progress on this phase.

4. Installation of the very high-pressure bomb and pressurizing equipment has been completed. On completion of preliminary tests, this apparatus will be ready for operation.

Part II - Ignition Studies

5. A program of ignition investigations has been planned. It is intended that various types of ignition will be investigated to determine the most desirable method. This study will cover (1) ignition delays, (2) the effect of the character of ignition on the rate of pressure rise, (3) the minimum pressures at which ignition is sustained, and (4) the effect of loading density in influencing the burning rate and maximum pressure obtained.

6. The bomb to be used in the ignition studies is of the blow-out type. By selection of the proper thickness of blow-out disc, maximum pressures obtained can be controlled within reasonable limits. Thus it will be possible to operate up to loading densities approaching 1.0 without reaching exceedingly high pressures providing detonation does not occur. The bomb has a volume of approximately 12 cc. Pressure-time traces will be recorded using an Aberdeen, resistance-type pressure gauge and a Polaroid-Land camera. An expanded view sketch of the bomb is shown in Figure 2.

Part III - Stability and Compatibility Studies

7. The closed system compatibility studies described in references (b) have continued during the present period. The compatibility of various mixtures of hydrazine, hydrazine nitrate and water with polyethylene, polystyrene, nylon, teflon, aluminum and titanium is being studied for periods up to one year at room temperature. Each material is tested in four solutions having the following compositions:

Solution	% Hydrazine	% Hydrazine Nitrate	% Water	% Ammonia
W	97.5	0.0	1.9	0.7
X	78.4	18.1	3.0	0.5
Y	19.6	78.4	1.8	0.2
Z	44.9	45.3	9.4	0.4

8. Each piece of material, 3/8" x 4" x 1/8", was placed in a 10-ml test tube containing 3 ml of solution. The tube was placed in a large pyrex flask which was then sealed off. Pressures are read from an open tube mercury manometer sealed into the flask.

9. Compatibility of the materials with the solutions is based on (1) the rate and magnitude of gas evolution, (2) macroscopic examination of the test strip, (3) comparison of weight and physical dimensions before and after test, and (4) by analysis of the solution before and after the test. However, the most significant index of compatibility is provided by points (1) and (4). The gas evolution for periods up to 238 days at room temperature is shown in Figures 3 to 10. Table I presents the data for those tests that have been concluded. All of these except aluminum 2S in solution Z were discontinued because of breakage or other accident to the apparatus. Aluminum 2S in solution Z was discontinued because of the rapid rate of pressure rise in the system. All of the control solutions have been continued. The quantities of gas evolved for the last 100 days of observation for all the tests still continuing are given in Table II.

10. The results presented in Table I indicate that polystyrene and nylon are compatible with the solutions tested although some decomposition of the solutions has occurred. The erratic behavior of aluminum still is unexplained. However, as indicated in Table II, a repeat test of aluminum 2S in solution Y has shown little gas evolution. Further tests with aluminum at 160°F may afford more definite conclusions regarding the compatibility of aluminum with solutions containing hydrazine and hydrazine nitrate.

Part IV - Impetus Measurements

11. The impetus of various hydrazine-hydrazine nitrate mixtures has been reported in reference (b). In these measurements the maximum pressures obtained in closed bomb firings were multiplied by the volume of the vessel to give approximate impetus values. These values would more nearly correspond to the theoretical predications based on adiabatic flame temperature calculations if corrections for low maximum pressure due to heat loss were applied. Crow and Grimshaw (reference (d)) suggest a method for correcting for loss of pressure due to cooling. If P_o is the observed pressure and P the pressure that would have been observed if no cooling had occurred during burning then $P = \dfrac{P_o}{1-K\sqrt{t}}$

where t is time to observed maximum pressure. The coefficient K can be determined by burning equal quantities of the liquid in two tubes of different diameter and recording P-T curves. Alternatively, the bomb may be pre-pressurized at two different pressures, using the same quantity of propellant and again noting P_o and t.

12. The equation of state may then be written

$$P(V_o - W_p \lambda_p) = W_p NRT = W_p F_p$$

where P = corrected observed pressure

V_o = volume of empty, closed bomb

W_p = weight of liquid charge

λ_p = covolume per unit mass of propellant gas

F_p = impetus or force constant of the propellant

However, if the igniter produces gas, a correction must be applied. The impetus and covolume of the igniter is estimated by firing two charges of the igniter at different loading densities and solving the equation of state.

$$P(V_o - W_1 \lambda_1) = W_1 F_1$$

Therefore, for a charge W_p of liquid propellant and charge of igniter W_1, the equation of state becomes,

$$P(V_o - W_1 \lambda_1 - W_p \lambda_p) = W_1 F_1 + W_p F_p$$

or

$$F_p = \frac{P(V_o - W_1 \lambda_1 - W_p \lambda_p) - W_1 F_1}{W_p}$$

If the bomb is pressurized prior to the ignition of the propellant, the equation becomes,

$$P(V_o - W_1 \lambda_1 - W_p \lambda_p - W_g \lambda_g) = W_p F_p + W_1 F_1 + P_g V_o$$

where, W_g = the weight of the pressurizing gas

λ_g = covolume of the gas

P_g = pressure of vessel prior to ignition

Then, solving for impetus,

$$F_p = \frac{P(V_o - W_1 \lambda_1 - W_p \lambda_p - W_g \lambda_g) - W_1 F_1 - P_g V_o}{W_p}$$

Part V - Detonability Studies

13. Detonability studies as reported in reference (c) will be extended to cover card sensitivity tests on a series of solutions. In these tests, the card value of the test charge is determined by finding the number of cards required between the 50-gram tetryl pellet and the test charge in

order to attenuate the shock to the extent that the test
charge is not detonated. The materials for these tests
have been assembled and are awaiting the time and availabil-
ity of personnel.

## Part VI - Evaluation of Analytical Methods

Introduction

14. There has been developed during the past year an analyti-
cal procedure for the determination of hydrazine, hydrazonium
salts and ammonia which has been quite useful for the analysis
of liquid propellant compositions composed of hydrazine, hydra-
zine nitrate, water, and small amounts of ammonia.

15. The chief advantages of the procedure described below are
simplicity and speed with adequate accuracy. The procedure
employs successive acidimetric titrations on a single sample
as follows:

a. Neutralization of the sample with standard acid to
determine the total basic components (hydrazine and ammonia).

b. Reaction of the hydrazonium ion with excess acetone
forming dimethylazine, and titration of the acid liberated
with standard base. This determines the sum of free and com-
bined hydrazine (hydrazine and hydrazine salts).

$$N_2H_5^+ + 2CH_3COCH_3 \longrightarrow (CH_3)_2C=NN=C(CH_3)_2 + 2H_2O + H^+$$
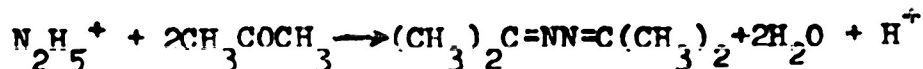
c. Reaction of the ammonium ion with excess formaldehyde
forming hexamethylenetetramine, and titration of the acid lib-
erated with standard base. This determines ammonia.

$$4NH_4^+ + 6HCHO \longrightarrow (CH_2)_6N_4 + 6H_2O + 4H^+$$

d. Subtracting the result for ammonia from the result
for total basic components determines hydrazine. Subtracting
the result for hydrazine from the result for the sum of free
and combined hydrazine determines hydrazine salts. The re-
mainder of the sample is assumed to be water.

Experimental Procedure

16. The analytical procedure was evaluated by comparison with
the direct iodate method for the determination of hydrazine.

Reagents

a. Potassium iodate (KIO_3), 0.1260 moles per liter, standardized potentiometrically against samples of arsenic trioxide primary standard.

b. Sodium hydroxide (NaOH), 0.1888 moles per liter, CO_2 free, standardized against samples of potassium acid phthalate primary standard, using a Beckman pH meter to determine end points.

c. Nitric acid (HNO_3), 0.1709 moles per liter, standardized against the standard sodium hydroxide solution, using a Beckman pH meter to determine end points.

d. A standard solution of hydrazine (N_2H_4), containing approximately 5.4 grams of N_2H_4 per liter, prepared using freshly boiled distilled water. This solution was kept under an atmosphere of nitrogen. A 25.00-ml automatic pipet was employed for measuring samples. The hydrazine solution was standardized, and re-standardized frequently, by the direct iodate method. This method involved the introduction of the sample into 8 normal aqueous hydrochloric acid solution and titration with standard potassium iodate. The end point was determined potentiometrically using a platinum-tungsten electrode pair.

e. A standard solution of ammonia, containing approximately 1.5 grams of ammonia (NH_3) per liter, and standardized against the standard nitric acid solution, using a Beckman pH meter to determine end points.

f. Acetone, reagent grade

g. Formaldehyde solution, 37%, reagent grade

h. Indicator solution, containing 0.08% bromocresol green, 0.05% methyl red, 0.05% bromothymol blue, 0.05% phenol red, all dissolved in 95% ethyl alcohol, and neutralized to pH8 with sodium hydroxide solution.

Procedure

17. a. Pipet an excess (2.5 ml) of standard nitric acid into a 250-ml beaker.

b. Pipet 25.00 ml of standardized hydrazine solution into the acid solution, agitating the beaker to permit rapid mixing.

c. Pipet the desired volume of standardized ammonia solution into the beaker.

*d. Add three drops of the indicator solution. The color of the solution should be pink, indicating that the pH is less than 4.5.

*e. Stirring the solution mechanically, backtitrate with standard sodium hydroxide solution dropwise until the color changes from pink to orange-yellow, indicating a pH of 4.7. Record the milliliters of sodium hydroxide required for the backtitration.

*f. Add 10 ml of acetone, and continue adding standard sodium hydroxide solution, rapidly at first, to neutralize the acid liberated by the formation of dimethylazine. When the color of the solution changes from yellow to green, stop the addition of sodium hydroxide for about one minute, then resume the titration dropwise until the first appearance of blue in the green solution, indicating a pH of 7.6. Calculate the milliliters of standard sodium hydroxide used after the addition of acetone by subtracting the milliliters required for the previous titration, from the buret reading after the addition of acetone, and record this value.

*g. Add 10 ml of 37% formaldehyde solution to the beaker and continue the addition of standard sodium hydroxide dropwise, until the color of the solution changes from green to purple, indicating a pH of 7.9. Be sure the purple color is permanent before recording the milliliters of standard sodium hydroxide required. This value is calculated by subtracting the milliliter values for the two previous titrations from the buret reading.

*h. Formaldehyde solution is slightly acid. Ten milliliters require about 0.3 ml of the standard sodium hydroxide to neutralize it to pH 7.9. Determine the formaldehyde blank by repeating step g for a few representative determinations and averaging the values for the milliliters of standard sodium hydroxide required.

*i. If the pH meter is used to determine end points, omit the colorimetric indicator solution. Record graphically the pH values for successive additions of standard sodium hydroxide solution for all titrations. Record values from at least 0.5 ml before each end point to at least 0.5 ml beyond, recording for each added drop near the end point. The end point is represented by the point of inflection for each curve. At the conclusion of step f and step g add accurately about one milliliter of standard nitric acid before proceeding. This added acid must be considered in the calculations.

* For the procedure employed for determinations using the pH meter see "Procedure, Step 1".

Calculations

18. Let:

V_h = milliliters of standard nitric acid used.

V_{bk} = milliliters of standard sodium hydroxide used for the backtitration.

V_a = milliliters of standard sodium hydroxide used after the addition of acetone.

V_f = milliliters of standard sodium hydroxide used after the addition of formaldehyde.

V_{bl} = milliliters of standard sodium hydroxide used for the formaldehyde blank.

Then,

$$\text{Moles of total } N_2H_4 = \frac{.1888 \, V_a}{1000} \qquad (1)$$

$$\text{Moles of } NH_3 = \frac{.1888 \, (V_f - V_{bl})}{1000} \qquad (2)$$

$$\text{Moles of } NH_3 + \text{free } N_2H_4 = \frac{.1709 \, V_h - .1888 V_{bk}}{1000} \qquad (3)$$

$$\text{Moles of free } N_2H_4 = (3) - (2)$$

$$\text{Moles of } N_2H_5^+ = (1) - (4)$$

19. The end points for the first five samples used in the evaluation of the analytical procedure were determined with a Beckman pH meter. These results are given in Table III. The values presented in Table IV were obtained by using the colorimetric indicator mixture to determine end points. Figures 10 and 11 show representative titration curves obtained by plotting pH values against milliliters of standard sodium hydroxide solution for the three titrations performed on a single sample. The mixed indicator used was found to give sharp color changes at the pH values corresponding to the inflection points.

Discussion

20. As the analytical method is presented here, two results for hydrazine are obtained in the analysis of each sample. The

first of these is derived from the neutralization with standard acid of free (basic) hydrazine. If, however, a sample containing a salt derived from hydrazine and a strong acid were neutralized with standard acid, no analysis for the hydrazine contained in the salt would be obtained. Immediately before the addition of acetone, all of the hydrazine contained in the sample is present as the hydrazine salt of a strong acid. Acetone liberates the acid by reacting with the hydrazine, forming dimethylazine, which is a much weaker base than hydrazine. This acid, when titrated with standard base, permits a determination of the sum of the free and combined hydrazine present in the sample originally. By subtracting the result for free hydrazine from the result for total hydrazine, the quantity of hydrazine originally present as the salt of a strong acid can be determined. The results of this evaluation indicate that free hydrazine alone can be determined with an error of -0.3%, with a standard deviation of 0.4% when employing the pH meter to determine end points, and with an error of -0.6%, and standard deviation of 0.4% when employing the colorimetric indicators. Figures for hydrazine salts alone, with no free hydrazine, would be the same. The accuracy and precision values for mixtures of hydrazine and hydrazine salts would be less favorable since the sample size is determined by the sum of free and combined hydrazine.

21. Table V presents data showing estimated accuracy for the analysis of the tri-component system hydrazine, hydrazine nitrate, water, using samples containing about 0.15 grams of total hydrazine, standard acid and base solutions approximately 0.15 normal, and employing the colorimetric indicator solution. The values for Table V were estimated as follows:

Error for Free $N_2H_4 = \dfrac{A}{B} \times C$

Error for $N_2H_5NO_3 = \dfrac{A}{D} \times C \times \dfrac{E}{F}$

Where:

A = grams total N_2H_4 in sample

B = grams free N_2H_4 in sample

C = average error for free N_2H_4 from Table I

D = grams N_2H_4 combined as $N_2H_5NO_3$

E = molecular weight of $N_2H_5NO_3$

F = molecular weight of N_2H_4

When water is present, the sample weight is increased so that all samples contain 0.15 grams of total hydrazine.

22. Ammonia, like hydrazine, is basic in aqueous solution.
Consequently, the acidimetric determination of free hydrazine
requires a correction for the amount of ammonia present in
the sample. Since ammonia is nearly always present in hydrazine
solutions, a determination of ammonia is therefore a necessary
part of the procedure. This evaluation includes a number of
samples with various known amounts of ammonia added to the
standard hydrazine solution, up to 12.5% of the weight of
hydrazine. Since virtually all of these samples show more
ammonia present than was introduced into the original samples,
and since the quantity of this excess ammonia remains constant
regardless of the amount of added ammonia, it is concluded
that all samples of the standardized hydrazine solution contained
approximately 0.0003 grams of ammonia. The results of the
determinations of samples with added amounts of ammonia indicate
that ammonia can be determined with an error of 1% at 10%
ammonia in hydrazine, 2% at 5% ammonia in hydrazine, and 50%
at 0.2% ammonia in hydrazine. The values for percent average
deviation are the same as the values for percent error.

23. It is recommended that any application of the analytical
method follow as closely as possible the procedure and conditions
of this evaluation. In addition, sampling should be done so as
to prevent access of air to basic solutions containing hydrazine,
since hydrazine reacts with oxygen and with carbon dioxide. It
is convenient to use a small tared glass bulb with a long, thin,
drawn capillary stem for sampling. The bulb is heated over a
small flame to expel some of the air. Immersing the end of the
capillary stem in the liquid to be sampled permits the liquid
to flow into the bulb as it cools. The end of the capillary is
sealed in a flame before the bulb is weighed. The bulb is broken under
an excess of standard acid with a stirring rod. Since acid
solutions of hydrazine are not affected by oxygen or carbon
dioxide, this assures that the hydrazine will not decompose.

24. Titration of samples using standard solutions whose
concentrations differ greatly from the concentration used for
the evaluation may result in greater error, caused by changes
in the pH values of the end points and in differences in the
magnitudes of these changes. It is suggested that standard
acid and base solutions be approximately 0.15 normal and that
the size of samples be adjusted so as to contain between 0.1
and 0.2 grams of total hydrazine.

25. Figure 11 shows that ammonia concentrations of 12.5%
repress the inflection obtained after the addition of acetone.
This indicates that free and combined hydrazine determinations
are less accurate at higher ammonia concentrations.

Table I

Compatibility Data for Tests that Have Been Discontinued

Material	Solution	Solution Composition %				Number of Days	Gas Evolved (ml)	Final Solution Composition %				Weight of Test Strip		
		N_2H_4	NH_4NO_3	H_2O	NH_3			N_2H_4	NH_4NO_3	H_2O	NH_3	Before	After	Change
Aluminum 2S	Y(A)	19.6	78.4	1.8	0.2	36	23.0	18.1	76.5	5.1	0.33	8.3138	8.3137	0.0001
Aluminum 2S	Z	44.9	45.3	9.4	0.4	112	202.8	42.1	48.7	8.2	2.0	8.2536	8.0863	0.1673
Polystyrene	Z	"	"	"	"	43	10.2	39.9	42.9	16.8	0.33	3.5758	3.5822	0.0064
Nylon	Y	19.6	78.4	1.8	0.2	167	11.0	16.2	77.9	5.6	0.32	3.5270	3.5153	0.0117
	Control Y	"	"	"	"	36	none	----	----	----	----	-----	-----	-----
	Control Y	"	"	"	"	167	7	----	----	----	----	-----	-----	-----
	Control Z	44.9	45.3	9.4	0.4	43	16	----	----	----	----	-----	-----	-----
	Control Z	"	"	"	"	112	16	----	----	----	----	-----	-----	-----

Table II

Ml of Gas Evolved During Last 100 Days of Observation

Solution	Controls	Aluminum 2S	Nylon	Polyethylene	Teflon	Polystyrene	Titanium
W	2	2	2	2	2	2	3
X	2	1	2	2	2	1	1
Y	3	2	-	4	6	2	5
Z	2	-	2	1	1	-	1

Table III

Titrations of Hydrazine-Ammonia Mixtures, pH Meter End Points

Sample, grams		Recovery, grams			Percent error		Difference grams
		Free	Total		Free	Total	
N_2H_4	NH_3	N_2H_4	N_2H_4	NH_3	N_2H_4	N_2H_4	NH_3
0.1406	0.0000	0.1405	0.1406	0.0004	−0.07	0.00	+0.0004
0.1406	0.0000	0.1404	0.1403	0.0003	−0.14	−0.21	+0.0003
0.1406	0.0000	0.1404	0.1402	0.0002	−0.14	−0.29	+0.0002
0.1406	0.0177	0.1401	0.1398	0.0183	−0.36	−0.57	+0.0006
0.1406	0.0177	0.1392	0.1394	0.0182	−1.00	−0.86	+0.0005
				AVERAGE	−0.34	−0.39	+0.0004
			STANDARD DEVIATION		0.39	0.37	0.0003

Table IV

Titrations of Hydrazine-Ammonia Mixtures, Color Indicated End Points

Sample, grams		Recovery, grams			Percent Error		Difference grams
		Free	Total		Free	Total	
N_2H_4	NH_3	N_2H_4	N_2H_4	NH_3	N_2H_4	N_2H_4	NH_3
0.1401	0.0000	0.1387	0.1395	0.0005	-1.00	-0.43	+0.0005
0.1401	0.0000	0.1387	0.1392	0.0006	-1.00	-0.64	+0.0006
0.1401	0.0000	0.1390	0.1394	0.0004	-0.79	-0.50	+0.0004
0.1401	0.0000	0.1390	0.1396	0.0006	-0.79	-0.36	+0.0006
0.1391	0.0000	0.1386	0.1392	0.0004	-0.36	+0.07	+0.0004
0.1391	0.0000	0.1385	0.1384	0.0002	-0.43	-0.50	+0.0002
0.1391	0.0000	0.1380	0.1386	0.0004	-0.79	-0.36	+0.0004
0.1391	0.0000	0.1376	0.1383	0.0005	-1.07	-0.57	+0.0005
0.1391	0.0000	0.1372	0.1382	0.0005	-1.36	-0.64	+0.0005
0.1391	0.0000	0.1378	0.1383	0.0005	-0.93	-0.57	+0.0005
0.1391	0.0000	0.1380	0.1385	0.0003	-0.79	-0.43	+0.0003
0.1391	0.0000	0.1378	0.1383	0.0004	-0.93	-0.57	+0.0004
0.1401	0.0014	0.1395	0.1401	0.0018	-0.43	0.00	+0.0004
0.1401	0.0022	0.1392	0.1397	0.0026	-0.64	-0.29	+0.0004
0.1401	0.0022	0.1388	0.1394	0.0026	-0.93	-0.50	+0.0004
0.1401	0.0027	0.1389	0.1397	0.0032	-0.86	-0.29	+0.0005
0.1401	0.0041	0.1399	0.1407	0.0041	-0.14	+0.43	0.0000
0.1391	0.0052	0.1393	0.1395	0.0049	+0.14	+0.29	-0.0003
0.1391	0.0052	0.1392	0.1395	0.0049	+0.07	+0.29	-0.0003
0.1391	0.0052	0.1385	0.1385	0.0053	-0.43	-0.43	+0.0001
0.1391	0.0052	0.1381	0.1386	0.0055	-0.71	-0.36	+0.0003
0.1391	0.0052	0.1381	0.1386	0.0055	-0.71	-0.36	+0.0003
0.1391	0.0052	0.1383	0.1386	0.0054	-0.57	-0.36	+0.0002
0.1391	0.0052	0.1389	0.1391	0.0054	-0.14	0.00	+0.0002
0.1391	0.0052	0.1386	0.1386	0.0054	-0.36	-0.36	+0.0002
0.1406	0.0177	0.1406	0.1405	0.0180	0.00	-0.07	+0.0003
0.1406	0.0177	0.1399	0.1400	0.0178	-0.50	-0.43	+0.0001
			AVERAGE		-0.57	-0.29	+0.0003
		STANDARD DEVIATION			0.37	0.29	0.0002

Table V

Estimated Accuracy for Analysis of Mixtures Containing Hydrazine, Hydrazine Nitrate, and Water in Relative Percent.

Ratio % Hydrazine to % Hydrazine Nitrate	Sample Size, Grams Hydrazine Plus Grams Hydrazine Nitrate	Percent Error	
		Hydrazine Determination	Hydrazine Nitrate Determination
1:0	0.15	-0.6	---
7:1	0.16	-0.6	-7.2
3:1	0.18	-0.7	-3.6
5:3	0.20	-0.8	-2.4
1:1	0.22	-0.9	-1.8
3:5	0.26	-1.0	-1.4
1:3	0.30	-1.2	-1.2
1:7	0.36	-2.4	-0.8
0:1	0.45	---	-0.6
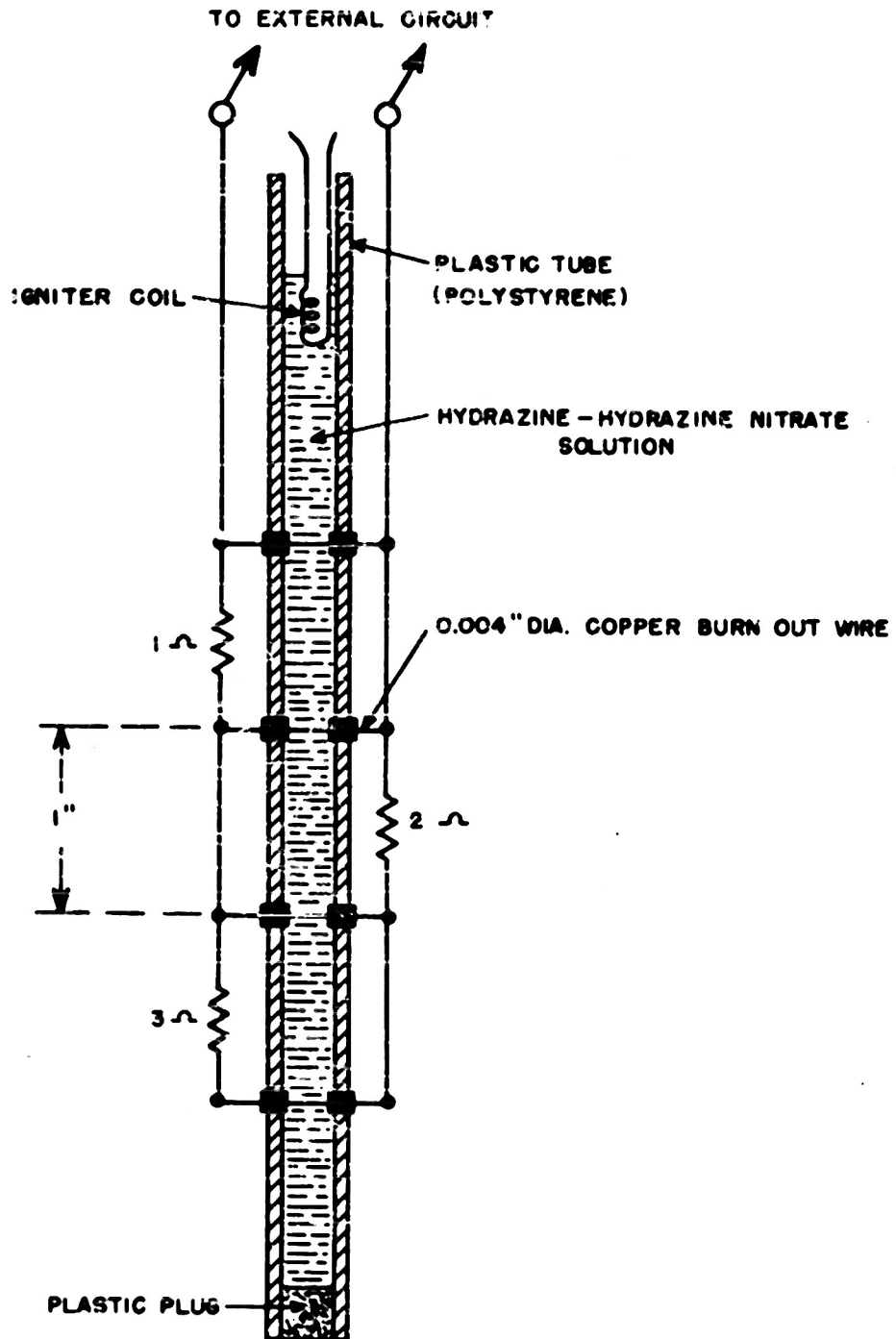
TO EXTERNAL CIRCUIT

FIG. I BURNING RATE TUBE

MK 42 IGNITION ELEMENT

O-RING

CAP

O-RING

TO GAUGE

TO VALVE

BODY

SEALING WASHER

O-RING

SHEAR WASHER

BLOWOUT DISK

BOTTOM

FIG. 2 IGNITION STUDY BOMB

CONFIDENTIAL

FIG. 3 CONTROLS

FIG. 4 TEFLON

DAYS

FIG. 5 TITANIUM

GAS EVOLVED (ML)
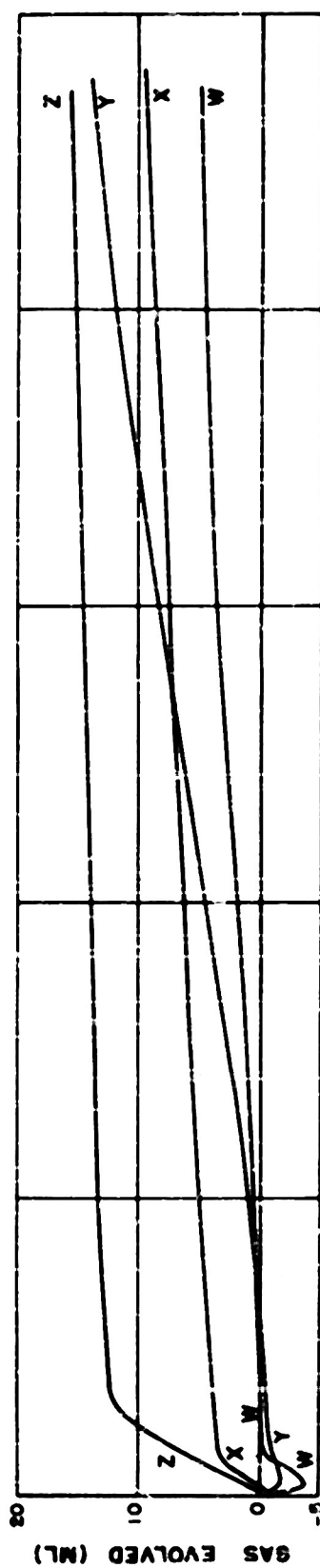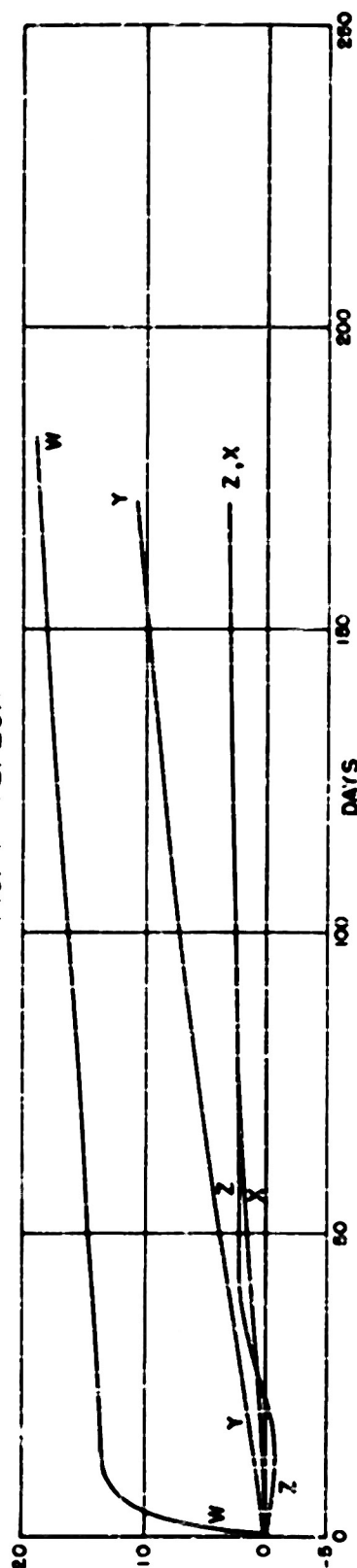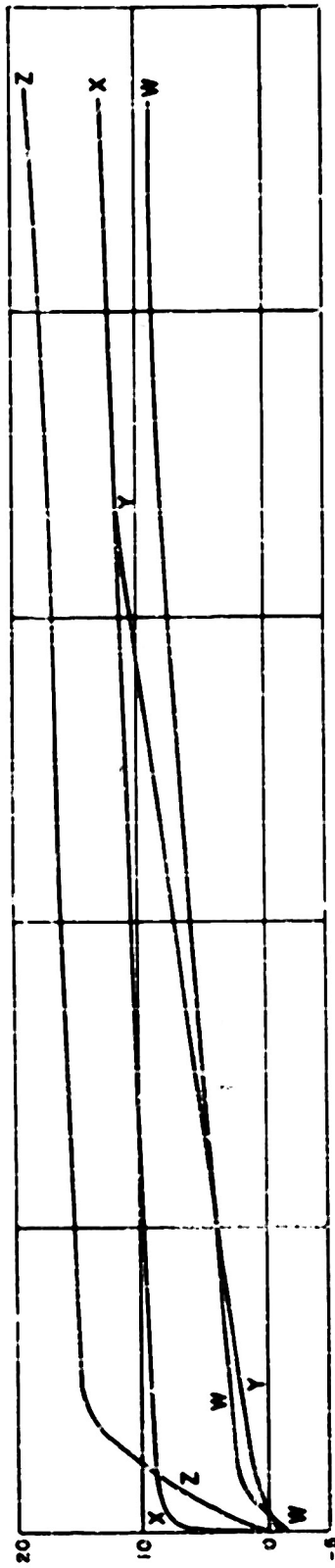
FIG. 6 NYLON
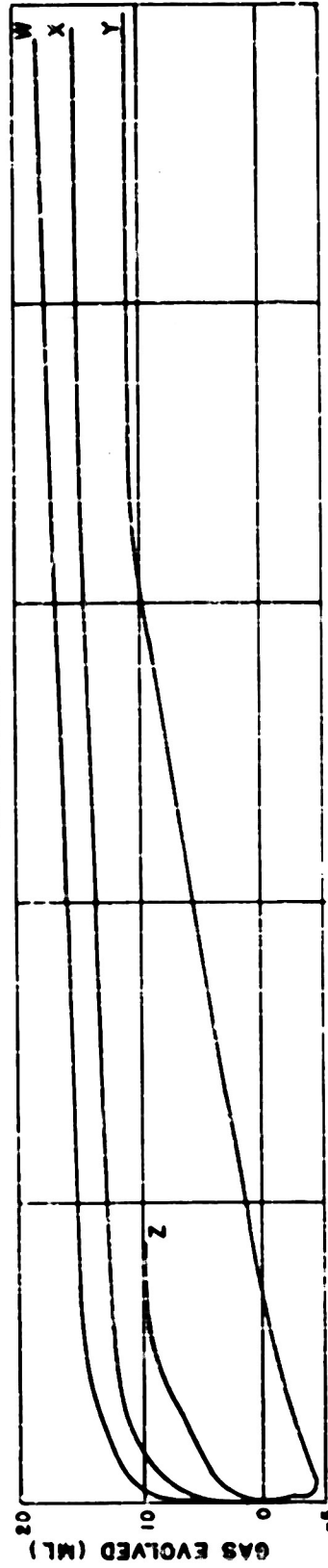
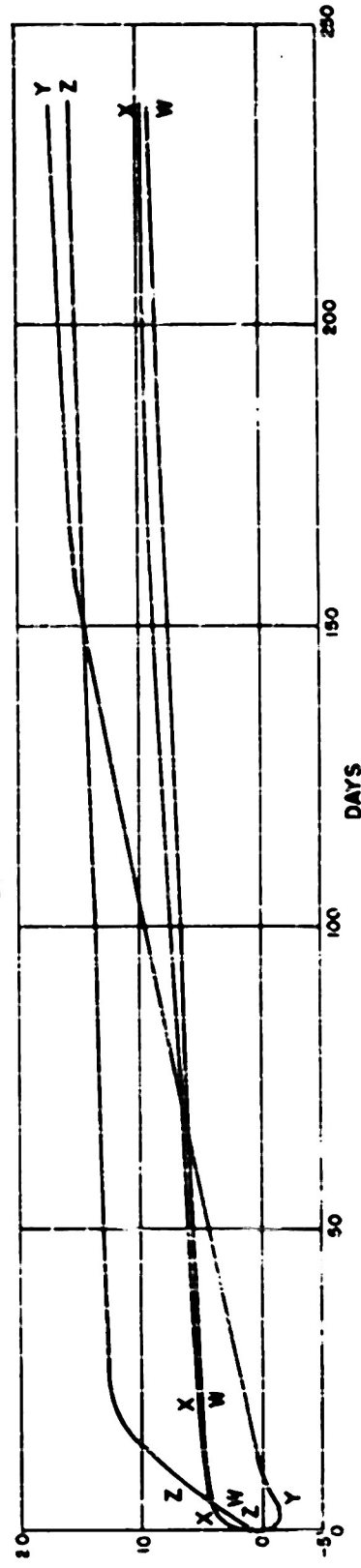FIG.7 POLYSTYRENE

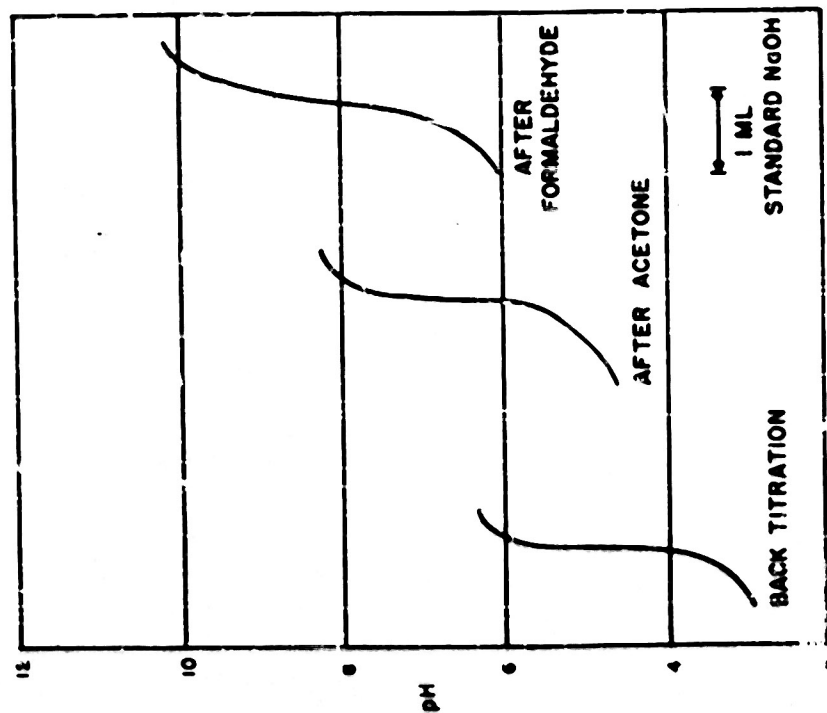FIG. 8 POLYETHYLENE

DAYS

GAS EVOLVED (ML)

FIG. 9 ALUMINUM 2S
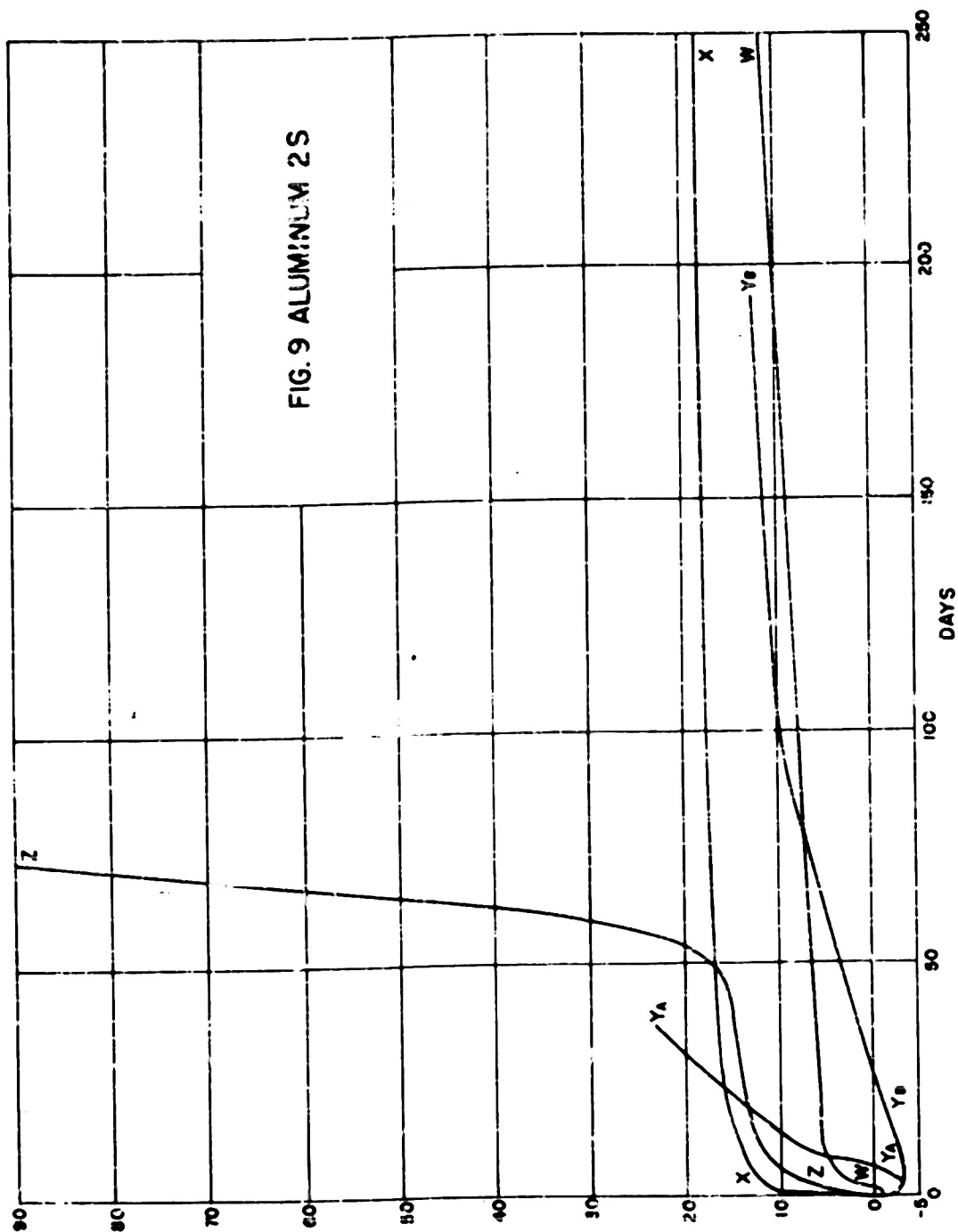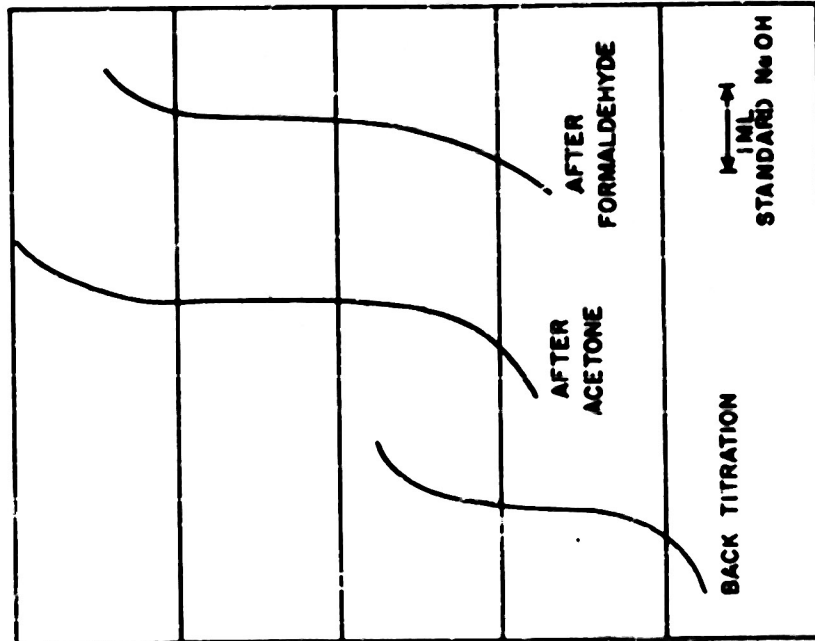
FIG. 10 CHANGES IN pH AT ENDPOINTS
(SAMPLE CONTAINING ABOUT 0.1% AMMONIA)

(SAMPLE CONTAINING ABOUT 12% AMMONIA)